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SiTRA Activity Status Report

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Abstract

We present a summary of last year activities within the JRA2 SiTRA subtask. Progress on front-end electronics, sensors R&D including very preliminary results from 2009 SPS test beams are briefly reported here.

1 Front-end electronics for microstrip detectors

A 130nm CMOS version of the SiTR_130 series chip [1, 2, 3, 4], with 88 readout channels including sampling and analog-to-digital conversion (ADC) has been developed in 2008 and tested in current 2009. In order to reduce material budget, integrate more channels and improve radiation hardness, we decided to use the Deep Sub Micron (DSM) integrated technology selected for the previous prototype and proven by it. The technology used in both cases is the 130nm CMOS technology provided by the United Microelectronics Corporation (UMC) in Taiwan. This is a new version of the chip we produced as deliverable in 2007 and successfully tested in test beam at CERN with a Silicon detector prototype. This new version includes a more sophisticated digital processing as compared to the one delivered in 2007.
Each channel comprises i) a low-noise charge preamplifier with a 30mV/Minimum Ionizing Particles (MIP) gain, ii) a pulse shaper operating between 0.5 and 2 microseconds peaking time (shaping time) in order to match various detectors lengths and readout conditions, and iii) a two dimensional structure of 8x8 analog sampler which allows storing up to eight successive events with eight samples per event. The latter is triggered by a scarifying analog section, summing three adjacent channels from the output of the shaper. Finally, all the samples are converted by a 12-bit parallel ADC. All the bias conditions of the circuit are controlled by a set of digital-to-analog converters (DAC). Finally, the digitized sample is serially read out in 40-bit data words containing charge, time, and channel and event information. The static consumption of the chip is simulated at 1.1mW per channel in the active mode and 145 μW per channel in the power down mode.
The tests of the chip indicate that the static consumption is about 1.35mW/channel. With a gain of 43mV/MIP and 2.6% of nonlinearity, the output of the shaper of the 88th channel (test channel) is linear up to 24 MIP's at the input.
Actually, a new circuit is under development with optimization of the silicon surface in such a way that 128 channels will be fitted in one silicon die. This circuit is developed using IBM CMOS 130nm technology in order to profit from the 4fF/m2 capacitance option and also the mixed-mode design flow that is developed and supported by CERN. This new version is intended to equip larger Silicon prototype devices and will be an important outcome of the EUDET project.A more detailed description of this new version can be found here [5]

2 Novel transparent microstrips sensors for alignment

The production and first optical measurements of novel infrared transparent microstrip detectors was carried out at CNM-IMB Barcelona, in collaboration with IFCA-Santander. The novel aspect of these detectors is the optimization of the thickness of the passivation layers to act as an antireflection coating. The transmittance to infrared light can thus be increased by almost a factor $\times 3$ with respect to standard microstrip detectors.

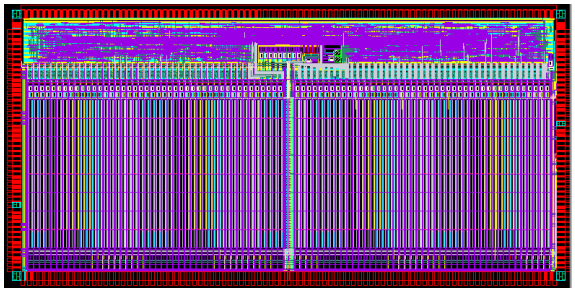

Figure 1: *Layout of the SiTRA_130 read out chip*

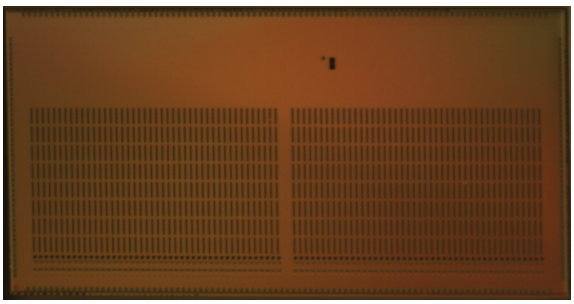

Figure 2: *Photograph of the actual SiTRA_130 chip.*

In previous works [6], [7] we identified the key parameters that determine the overall transmittance of a microstrip detector. These are divided into layout parameters (narrowing of the width of the aluminum electrodes) and structural changes (tuning of passivation thickness). These changes do not imply major modifications on the design of standard microstrip detectors.
The full optical simulation tool presented in [7] has been used to design a set of 5+1 wafers of baby sensors (each sensor is 1.5×1.2 cm^2) optimized for high transmittance at λ =1085 nm. Five of these wafers have openings of 1 cm diameter in the backelectrode to allow the transmitted light to propagate downstream. The last wafer however has a continuous back metalization and is used as a reference.
The choice of readout pitch was fixed to 50 μm. The width of the aluminum electrode and p-implant was varied from sensor to sensor within the wafer to study the dependence of transmittance on these layout parameters.
The transmittance for the 12 sensors, 2 control diodes, and these 4 optical structures is shown in Fig. 3. The computed transmittance is also shown, superimposed to these plots. This transmittance is calculated as a far field approximation of the exact fields computed at the exit window of the detectors. The details of this approximation will be given in a future EUDET note. The transmittance without the final passivation layer is already 20% higher than the measurement of a CMS sensor with the same pitch in good agreement with the simulation.
Deposition of the last layer of Si_3N_4 is taking place at the time of writing this note. Once this layer is deposited, we will carry out measurements of transmittance and reflectance

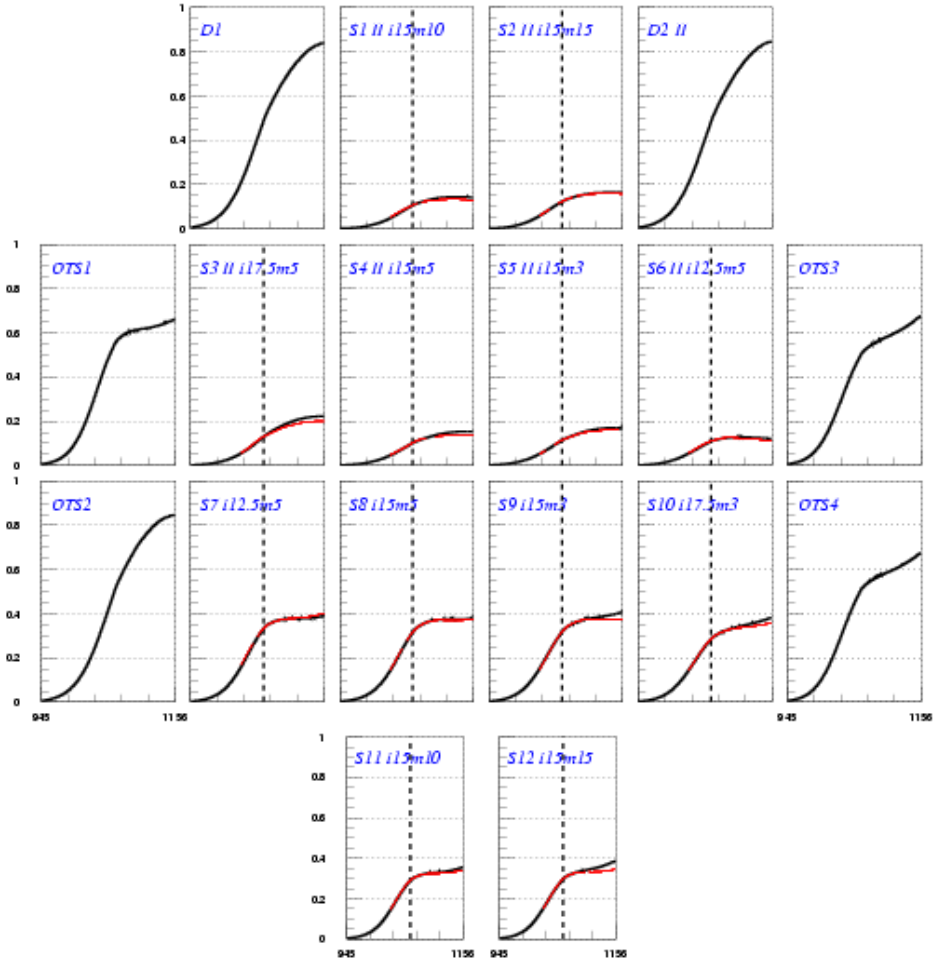

Figure 3: Measured transmittance (black) and calculated (red) for the 12 sensors of the wafer

of the fully completed structure. These measurements will be followed by dicing of the structures, electrical characterization and a comprehensive test using a laser and radioactive source . All these actions are envisaged during year 2010. A more detailed progress report can be found here [10].

3 Preliminary results from 2009 SPS test beams

During our assigned period (August 2009) of beam time in the CERN north area beam zone H6b of the SPS accelerator, we have used charged hadrons, mainly pions, with an energy of 120 GeV/c to simulate minimum ionizing particles. The DUT sensors have been installed in the center of the EUDET telescope. The scintillators, used for triggering, were connected to the TLU box, which provided trigger information to both, the EUDET telescope and the APVDAQ system

3.1 Standard CMS microstrip detectors modified for alignment

Besides the set of optimized sensors for IR maximum transmittance, two CMS sensors produced by Hamamatsu Photonics were beam tested during 2009 campaign. These were normal CMS sensors with a hole in the Al back metalization to allow light to pass through. Details of optical measurements undertaken prior to the mounting on modules were already given in [7]. Signal to noise ratio (SNR) in the alignment passage was compared (using the particle beam) to the same ratio in other zones of the sensors having the Al intact. Fig. 4 shows this comparison. The first point is well within the alignment passage and its performance is not degraded compared to Al covered areas. Signal with particles was also compared to the signal with laser beam (λ=1082 nm). Further analysis of this data is still ongoing.

3.2 Silicon Strip Sensors with integrated pitch adapters

Material reduction is a crucial point for inner tracking systems of all high energy physics experiments, especially for those based on silicon micro strip sensors. Our goal is to build a silicon module with as low material as possible. As a first step, we have designed silicon strip sensors which are equipped with integrated routing lines. These routing lines allow a readout chip to be directly connected to the sensor using wire bonds, omitting a pitch adapter.
The different layouts of these new silicon sensors are compiled such that all of them fit onto a single 4" wafer, which reduces the mask and setup costs to a minimum. A drawing of the full wafer is shown in figure 5. The wafer consists of five large sensors, surrounded by three sets of test structures. Four of the sensors have identical outer dimensions. Each of these sensors is equipped with 128 strips.

Standard Sensor (STD) The leftmost sensor on the wafer is a standard sensor without any routing or Pitch Adapter (PA). It is used for comparison reasons.

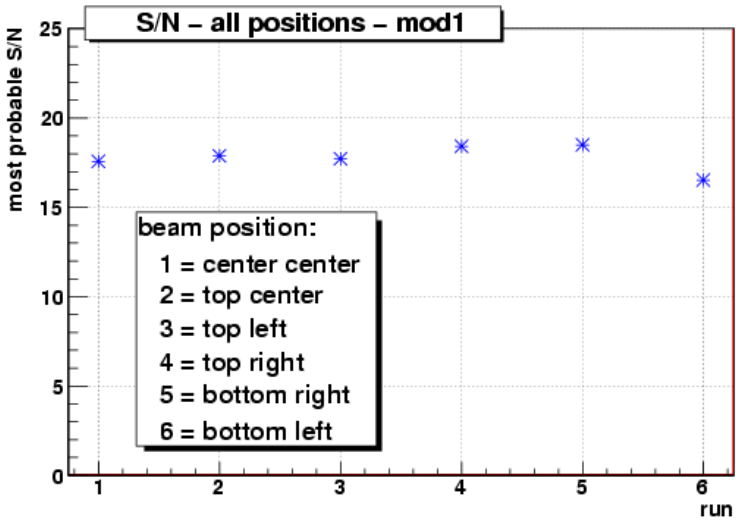

Figure 4: SNR measured with particles in the center of the detector (point 1) without Al, compared to the areas around the alignment passage.

Sensor with integrated PA on single metal layer (PAS) The sensor right to STD is using the strip metallization on one end as a fan-out to connect the strips to the bonding pads.

Sensor with integrated PA on double metal layers (PAD) The third sensor from the left is called PAD, since it has the Pitch Adapter implemented with double metal layers for both readout and routing metallisation. The connection from the strips (first metal) to the routing layer is done via via's through an insulating oxide layer, separating both metallizations.

Sensor with 512 Strips The bottom sensor as seen on of the wafer (shown in figure 5) is equipped with 512 readout strips which are shorter than the strips on the other sensors. It exists in two versions: The first version is a standard sensor with a single metallization. The second version implements the signal routing from the strip metallisation to the four readout chips using again a 2nd metal layer.

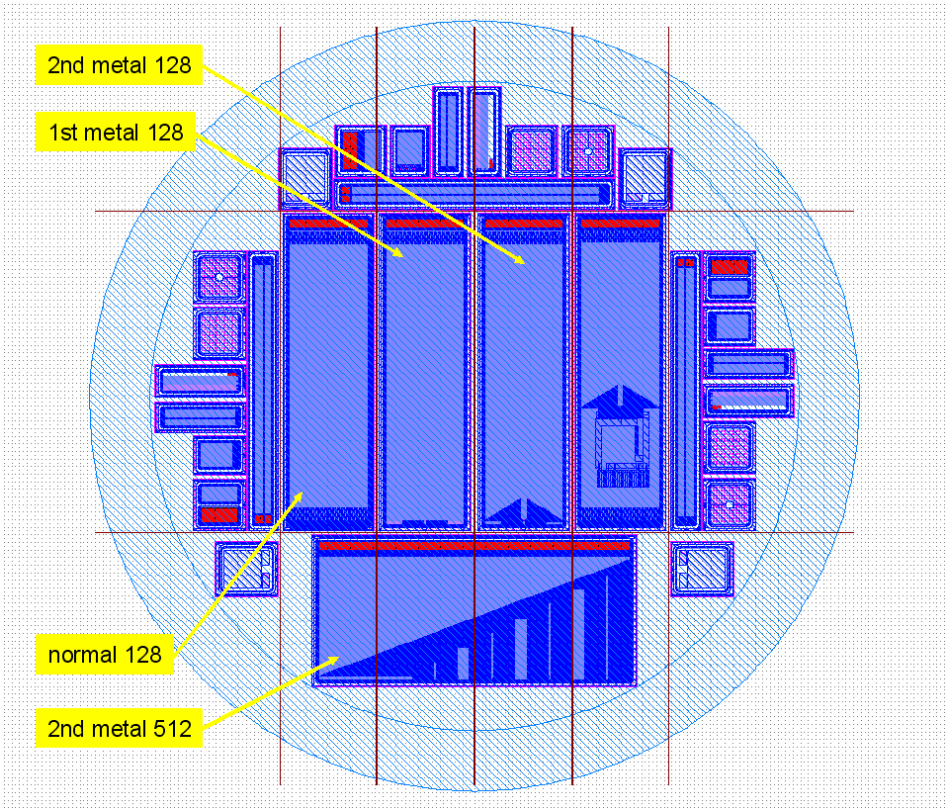

Figure 5: Layout of the full silicon wafer, as it was processed at ITE Warsaw. Red lines show the dicing (cut) lines.

Mechanical frames have been designed and manufactured using fibre-reinforced epoxy (Isoval R11), onto which the FE hybrid and the different DUT sensors have been glued. In total, eight modules have been built, two each with STD, PAS, PAD and 512-stip sensors. Examples of those modules are shown in Fig. 6 and Fig. 7
The data analysis is still ongoing, all results presented here are still preliminary and tentative. Among all data, we have selected to analyze the Signal-to-Noise-Ratio of the PAS sensors, first.
If a PAS sensor is hit in a region with no routing (green region in Fig 8), the signal-to-noise behaviour should be comparable to the STD sensor. However, if the sensor is hit in the routing region (blue region in Fig. 8), the SNR should decrease. This has been observed, where the SNR vs. strip number is uniform for the green region, while has a W-shape in the blue region. An extended description of this results can be found here [11].

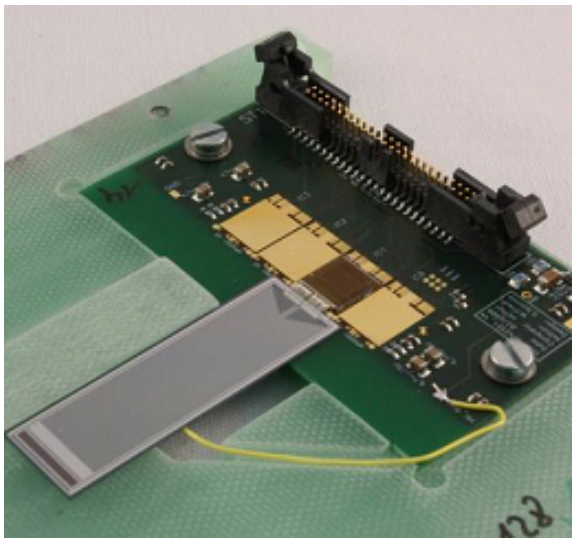

Figure 6: *PAS sensor connected to front-end hybrid equipped with a single APV25 readout chip*

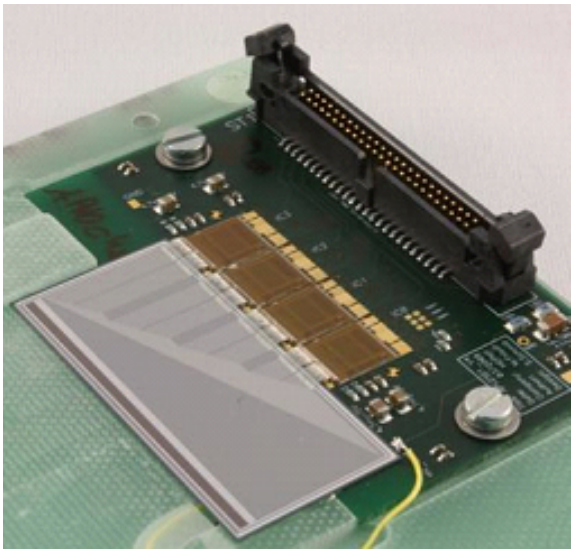

Figure 7: *512-strip-sensor connected to front-end hybrid equipped with four APV25 readout chips*

3.3 Combined Test beam with Silicon Detectors and EUDET Large TPC prototype

A new test beam was carried out at SPS after 2009 EUDET annual meeting, therefore this result was not reported during the plenary presentation. In November 2009 a first test beam including both, the Large TPC Prototype (LP) and two double layers of silicon strip detector modules was performed at DESY, using an electron beam with a momentum of 5.6 GeV/c. The LP was read out using Micromegas with T2K electronics. The aim of the development of the silicon double layers was to build a first prototype for the Silicon External Tracker (SET) layer for the International Large Detector (ILD) concept at the future International Linear Collider.
During the test beam period a total of 80,000 triggered events were collected and first data analysis started. A detailed account of this test beam including some preliminary results can be found here [12]

4 Conclusions

A 130nm CMOS version of the SiTR_130 series chip [1, 2, 3, 4], with 88 readout channels including sampling and analog-to-digital conversion (ADC) has been tested in 2009.
First measurements of new IR-transparent microstrip sensors optimized for transmittance were presented. The transmittance without the final passivation layer is already

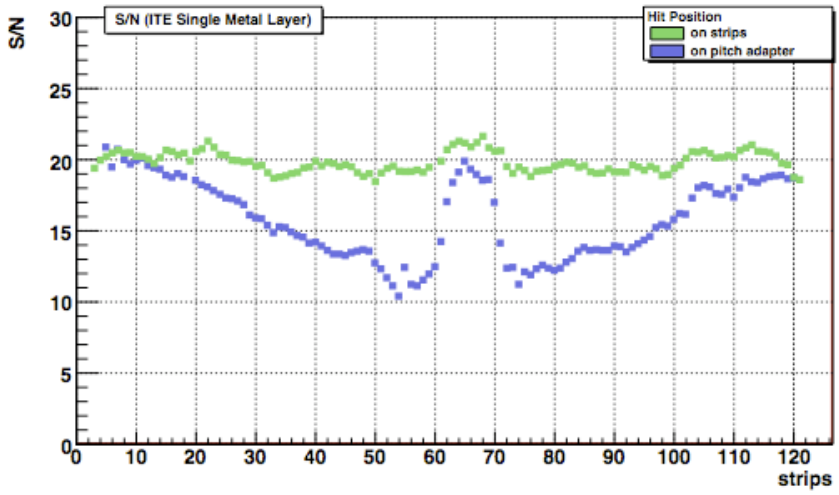

Figure 8: Signal-to-noise-plot for PAS sensor, for a particle beam hitting the sensor region with the integrated pitch adapter (blue dots) and for a particle beam hitting sensor outside this region.

20% higher than the measurement of a CMS sensor with the same pitch. Beam test measurements of new CMS-like detectors showed no degradation when comparing the SNR of the central alignment passage to standard areas with full Al metalization.
Sensors especially suited to test the possibility of integrating the pitch adapter into the sensor have been produced at ITE (Warsaw). Two different versions of this concept have been evaluated, while a standard sensor was used for comparison. The first, simpler version is using the strip metallization itself as fan-in. We have seen in the signal-to-noise numbers recorded during the beam test that those sensors are suffering from lower efficiency in the routing region, caused by crosstalk. The more complex sensor with dual metal layers does not suffer from this problem so severe. It still shows some crosstalk effects, but they are low compared to the simpler single-metal sensors.

Acknowledgment

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